DBP – Image Guided Prostate Interventions

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Prostate cancer

• One of every 6 men in the U.S. will be diagnosed
• 234,460 new cases in 2006
• ~1 million needle biopsies per year
• ~60,000 brachytherapy procedures per year
• USA incidence will double by 2025
• Add 10% for Canada
• Triple it for Europe
• South-East Asia is coming rapidly
• Multiple by 10 for BPH...

Image guided prostate interventions

• Diagnosis (core needle biopsy)
• Deliver localized therapy (seeds, injection)
• Imaging research validation (there is demand for irrefutable ground truth by histopathology of tissue collected from the same location)

Some facts of life

• Interventional images are nasty
  • Poor signal
  • Tool-tissue-imager interaction
  • Large inhomogeneities
  • Drastic tissue deformation and motion
  • Modalities coexist
  • Data fusion is necessary

Image guidance – MRI

PROS
• Sensitivity in detecting soft tissue abnormalities
• Excellent visualization of prostate and normal tissues
• Morphological, functional and molecular imaging

CONS
• Expensive
• Limited availability

Image guidance – TRUS

PROS
• Reasonable visualization of prostate and normal tissues
• Cheap
• Widely available
• Harmless

CONS
• Limited (poor) sensitivity
• Operator dependent
• Invasive
Image guidance – CT

**PROS**
- Available in RadOnc
- Useful in dose planning

**CONS**
- Poor sensitivity
- Poor contrast
- Harmful
- Not real time
- Moderately expensive

* Not used outside EBRT & post implant dosimetry

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Image guidance – C-arm fluoro

**PROS**
- Cheap
- Widely available (70% of brachy practitioners have in the OR)

**CONS**
- Limited soft tissue contrast
- Harmful radiation
- Extremely difficult to use computationally

* Not used outside prostate brachytherapy

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Current research scope

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<th>Trans-rectal</th>
<th>Trans-perineal</th>
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<tr>
<td>MR</td>
<td>Biopsy/Implants (coming: injections)</td>
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<tr>
<td>TRUS</td>
<td>Ablation (coming: biopsy)</td>
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<tr>
<td></td>
<td>Brachytherapy (coming: biopsy, ablation)</td>
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Project #1: Transrectal interventions in closed MRI

**Engineering:**
- The Johns Hopkins University

**Clinical:**
1. National Institutes of Health
2. Princess Margaret Hospital, Toronto
3. Memorial Sloan Kettering Cancer Center

**Funding**
- NIH/NIBIB 1R01EB002963, PI Fichtinger
- (2 more years, to submit competing renewal)

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In-scanner robotic assistant

Results in multiple clinical trials

- From concept to trials in 22 month
- 38 biopsies and seed placements
- Accuracy ~3 mm
- No severe adverse events

**Example #1**
- Target (red dot) before
- Needle void on target after
- Needle tract on target

**Example #2**
- Before
- Needle void on target after
- Needle tract on target after

Krieger et al. IEEE TMBE, 2005
Problems and needs

- Pre-op planning MRI/MRS - supine
- Intra-op intervention MRI - prone

Problems of MR prostate registration

- Fusion of pre-op information for improving intra-op execution, under the circumstances:
  - Completely different patient positions → large anatomical misalignment
  - Different imaging parameters
  - Different coils
  - Local deformation and surrounding tissue deformation → significant shape change → Non-rigid registration

Problems of MR prostate segmentation

- Localize prostate within scanned volume
- Critical: accuracy of segmentation → registration accuracy

  Challenges
  - Extreme detail in MRI/MRS → internal structures → too many edges near true boundary
  - No reliable region homogeneity or texture
  - Actual total gland (TG) boundary blends into surrounding tissues
  - Large variation in shapes
  - Variable edge profile within slice and across slices
  - Variable imaging sequence across datasets

Problems of MR needle/seed/device tracking

Examples of susceptibility artifacts imaged using Single Shot Fast Spin-Echo (SSFSE) and Fast Gradient Recalled Echo (FOSE) sequences, with needles perpendicular to B0, and immersed in a NiCl solution. Dashed lines and crosses are actual needle shaft and tip, while dotted lines and circles indicate detected artifact.

Project #2: Transperineal interventions in closed MRI

Engineering:
Brigham and Women’s Hospital
Johns Hopkins University
Acoustic MedSystems/Burdette Medical

Clinical:
Brigham and Women’s Hospital

Funding
NIH/NCI 1R01CA111288-01, PI Tempany (5 more years)
DoD PC061118, PI, Fischer (2 more years)

In-scanner robotic assistant
Problems and needs

Covered earlier

Project #3: Transperineal brachytherapy under TRUS

Engineering:
Johns Hopkins University
Acoustic Medsystems/Burdette Medical
Clinical:
Johns Hopkins University

Funding
NIH/NCI 2 R44 CA096574-02, PI Burdette (3 more years)
NIH/NCI 1R21CA120232-01, PI Salcudean (2 more years)
DoD PC 050042, PI Song (1 more year)
DoD PC 050170, PI Jain (1 more year)
NIH/NCI SR44CA088139-04, PI Burdette (expired)
NIH/NCI R43CA099374-01, PI Burdette (expired)
NIH/NCI R01, PI Fichtinger – in submission

Approach 1: TRUS-guided robotic assistant

- Max dose to cancer, min dose everywhere else
- Maximize needle/seed placement accuracy w/ robot
- Localize needles and seeds in TRUS
- Analyze dose, optimize the remainder of the implant

Problems and needs

Anatomy segmentation

Organ segmentation, tissue tracking, seed & needle tracking

Approach 2: Registration of TRUS to C-arm

- C-arm fluoro shows seeds, TRUS shows anatomy
- Reconstruct seeds from C-arm and register to TRUS
- Analyze dose, optimize the remainder of the implant

More problems and needs

- Calibration, distortion correction, pose tracking of C-arm
- Bullet proof auto-segmentation of seeds and fiducials
**Project #4: Transrectal HIFU ablation under TRUS**

**Engineering:**
Johns Hopkins University
Acoustic Medsystems/Burdette Medical

**Clinical:**
Johns Hopkins University

**Funding**
NIH/NCI 1R41CA106152-01A1, PI Fichtinger
(Ph1 to expire, Ph2 to be submitted)

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**More problems and needs**

- Non-invasive monitoring w/ ultrasound

- B-mode image
- Gross-pathology

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**Current state in our clinical systems**

- Manual/semi-manual segmentation
- Contour-based registrations
- Legacy GUI & front-ends
- **INFINITE ROOM FOR IMPROVEMENTS**

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**Some perennial image analysis problems**

- Segmentation in TRUS and MRI
- Deformable registration of the prostate with ultrasound series, with MRI series, and across those
- Multi-dimensional statistical deformable atlas of the prostate, with associated probabilities of cancer and other clinically quantities
- Segmentation, tracking, and measurement of therapeutic substances used in prostate therapies, such as radioactive seeds, injections, etc., in ultrasound, MRI
- Reconstruction of brachytherapy implants in C-arm fluoroscopy
- Segmentation and tracking of surgical tools, such as needles and tissue ablatorats, in ultrasound and MRI
- Non-invasive temperature monitoring in ultrasound
- Tool & implant tracking in TRUS/MRI
- Tissue motion tracking in TRUS/MRI
- Predictive deformation models.....

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**Questions?**

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